Computational studies using finite element analysis for mitigating head injuries during helmeted impacts

Abstract

This study investigates helmeted head impact biomechanics using finite element analysis, emphasizing the mitigation of linear and rotational accelerations linked to traumatic brain injury. Key parameters affecting head kinematics—including anvil inclination, interfacial friction, helmet fit, shell thickness, retention system effects, and material behavior—were systematically examined under oblique impact conditions. Simulations revealed that friction at critical interfaces and helmet–headform mismatch significantly influence peak linear and rotational accelerations. The effects of shell thickness and impact-resistant coatings on thermoformed ABS shells were also evaluated, indicating potential for acceleration reduction and weight optimization. Advanced helmet technologies, namely MIPS and WaveCel systems, were analyzed numerically. The MIPS system demonstrated rotational acceleration reduction in selected impacts, while WaveCel simulations did not consistently show the proposed deformation mechanism. Based on these findings, a novel dual-density foam helmet design was proposed. The results demonstrate that optimized hybrid foam liners can significantly reduce both linear and rotational head accelerations, contributing to improved helmet safety design.